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THE AMERICAN
METEOROLOGICAL JOURNAL.

VOL. VII. ANN ARBOR, OCTOBER, 1890. No. 6.

ORIGINAL ARTICLES.

CYCLICAL PERIODICITY IN METEOROLOGICAL PHENOMENA.

BY E. DOUGLAS ARCHIBALD.

The subject of the present essay has been suggested to the writer, first by the fact that the possibility of the existence of a fairly regular recurrrence of such a variable and uncertain thing as weather led to his enrolling himself as a private in the meteorological army, and secondly by the very suggestive address recently delivered by Professor Davis at a meeting of the New England Meteorological Society at Providence, on April 1890—on secular periodicity to climate. As the writer is simply traveling through America on his way to Australia and has no means of access to his meteorological library he must apologize if his remarks take a general and discursive rather than a particular and numerically accurate character. The chief desire of all who cultivate Meteorology, or any other science, is to arrive first at qualitative and then at quantitative laws, and since, in the practical application of meteorology more than perhaps in that of any other science the elements of *time* is all important, great efforts have been made to discover whether the conditions, ephemeral or long continued, which constitute what is termed weather, are liable to periodical recurrence.

The fascination which such an idea as recurrence possesses for the human mind is indisputable, and this, together with the

fact that for the most part the discovery of any such law is attained by empirical and inductive methods within the grasp of everybody rather than by rational and deductive methods which can only be wielded by those who understand the higher mysteries of the subject have continued to attract a legion of amateurs as well as officials to work in this field. Dismissing the wild ideas of some who might be termed, meteorological lunatics, and who, unfortunately, appear to be as prolific as they are malific, let us examine some of the results which have been achieved by various investigators and the prospect they hold out to us of any practical and material, as well as theoretical, advances being secured for the science. Investigators may be divided into two classes: (1) those who examine data without any previous bias and who, inductively and empirically, discover some apparent recurrence of some one or more meteorological conditions, and, (2) those who are armed with some previous expectation of the term of the period founded on some real or supposed analogous period in some other causal cosmical phenomenon.

Within this latter group are comprised all those who attempt to connect diurnal and secular recurrences of meteorological phenomena with certain known periods of solar, lunar and planetary position and revolution, as well as with the less regular but still recurring periods of solar activity as manifested by the sun's spots and gaseous prominences.

The number and variety of all such periods is quite wonderful. They vary from a few hours up to 122 years. Some, like the diurnal barometric tide, are well defined and certain. Others, like the longer periods in the aurora and air temperature, are somewhat problematical. In reviewing the entire problem, one of the first questions we feel inclined to ask ourselves is, have we any reason to expect that there may be any periods other than those which can be distinctly related, epoch for epoch, with known astronomical recurrent changes? The first class of cycle hunters evidently proceed on this assumption, and if we consider for a moment we shall have to admit its probability since determinant meteorological phenomena are partly cumulative and partly cataclysmic. Where the conditions constantly involve stable equilibrium they are steadily cumulative and where instability ensues after a certain period, as in a tornado or thunder-storm or more widely in a cyclone, they are cataclysmic. It is easy to understand, for example,

why there should be, besides diurnal and seasonal periods in rainfall, temperature, thunder, tornadoes and cyclones, certain recurring periods in one or more of these elements, introduced by local conditions such as geographical position, nature of soil and aspect, and other causes which it would be difficult to differentiate, but which operating together produce an integral function which, if they are tolerably constant, may tend to recur in a regular period whose length could not have been foreseen.

In this category, for example, I would be inclined to place the variously estimated polydiurnal storm periods, the periodic rises and checks in the annual mean daily temperature curve, especially the cold weather of May in Europe, the Indian summer in September, the cyclone periods of May and October in the Bay of Bengal, and various other periodic phenomena which result partly from seasonal and partly from local conditions.

It is even conceivable that certain local conditions especially those depending on oceanic currents may not be able to cumulate or complete their cycle for a number of years and thus there may be some rational cause to favor and interpret cycles of three, seven, and even the forty-five year period of Köppen (for cold winters). It is evident, however, that so long as we confine our attention to the empirical determination of periodicities of this character we can never make much progress either towards prediction or a rational knowledge of the conditions which cooperate in causing the results we are investigating. In fact we have here a very good example of the failure of the purely inductive method to establish rational science. So long as the cycle hunter confines himself to his own locality, he discovers wonderfully regular periods in some if not all of his data and any little discrepancies that may irritate his love of regularity and harmony can be easily removed by a little judicious cooking of the data or smoothing of the curves. When, however, he widens his circle of operations and includes data from all parts of the world in his investigations, he is often amazed to find places where no such periods occur and others again where they occur in a precisely opposite place. Perplexed and disappointed thereupon, he too often resigns any further investigation not merely because the results are complicating but because the empirical method gives him no clue as to the possible causes of such divergence nor any hope that the apparent period in his own locality may be anything but a chance coincidence.

Another evil, arising from the careless exhibition of such contradictions, is, that they have been adverted to, by those who are adverse to the theory, in order to show that the supposed physical connection in either does not exist, or is of too slight and uncertain a character to be of any material service. Thus at the end of the three text-books written by Sprung, Scott, and Greely, the reader is told that the supposed connection between various elements of weather and the sun-spot curves has either no existence or else is too complicated and irregular to be employed as a material factor in weather forecasting. Granting this latter point so far as diurnal or short periods are concerned, I take it to be by no means proven that a broad and thorough investigation of the entire question for the whole world would not show periodic fluctuations large enough to enter as factors in *secular* weather, besides helping to elucidate the precise effects of an increase or decrease of solar energy on meteorological elements and thereby materially assisting towards the solution of many obscure points relating to the *origin* of *diurnal* as well as secular weather.

The plan I would recommend in such investigations is to adopt a well defined physical or astronomical period as a basis, and then to employ some rational working hypothesis until the results deduced thereupon fail to agree with the data, and it is found that in order to make them mutually and collectively harmonize, another, and it may be precisely opposite theory must be entertained. Were such a plan adopted by a body capable of working it on the scale commensurate with the character of the cause, such as a variation in solar energy which must affect the whole earth at one time independently of local conditions, I am confident that the entire science of Meteorology, both in its theoretical and practical aspects, would make an advance.

That this was felt to be the case some years ago by some whose labors have now unfortunately ended, is plain from the fact that a proposal was entertained by Professor Balfour Stewart, Professor Clerk Maxwell, Allan Broun and other well known names in the world of Meteorology and Physics to form a "cosmical club" in London, the members of which were to meet from time to time and discuss collectively and exhaustively all data and questions bearing on the relation between variations of solar energy or astronomical motions, and terrestrial Physics and Meteorology. Prof. Stewart communicated the news of this proposed plan in a letter to the writer, not long before his

decease, and it has often been the intention of the writer to endeavor to establish something of the sort, and dedicate it to the memory of that most earnest and enthusiastic and successful worker in this field of investigation. The possible cosmopolitan importance of the subject, especially the particular relation between solar and terrestrial energy, is shown by the prize offered some years back by the Dutch Academy of Science at Haarlem and won by Professor Herman Fritz in his exhaustive compilation, entitled "Ueber die Beziehungen zwischen der Sonnflecken Periode und Meteorologie," the work of Professsor Hahn of Leipzig, preceding this, and the attention paid to it by such men as Bezold, Köppen, Blanford, Chambers, Dr. Gould, Lockyer, Hornstein, Hill, Meldrum and others. Dr. Schuster has also reviewed the chief sporadic investigations which had been made up to that date, in a large print report to the British Association in (I think) 1884, but in all these cases little beyond mere compilation has been effected, and no serious attempt has been made to deal with the subject on a broad deductive basis. Until this is done, little progress can ever be hoped for. The relations will always remain sporadic, very often apparently contradictory, and wanting that cement of correlation and continuity, without which they will never be associated as the common effects of one universally acting cause.

An attempt was made by the writer in 1878 to sketch a deductive scheme* by which the hitherto irreconcilable results of a comparison of rainfall records with the sunspot period might be brought under one broad working hypothesis, and he has always regretted that a pressure of private work prevented his following up what appeared to be a most promising field. The working hypothesis employed, whether right or wrong, was conceived jointly by himself and Professor Hill of Allahabad, and helped towards the discovery which they both made simultaneously and which has since been established by Professor Hill on more extended data, that in years where the summer rainfall is scanty in Northern India the succeeding winter fall is above the average, and that these conditions tend to recur at or near the epoch of minimum sunspot area while precisely opposite conditions tend to recur about the period of maximum sunspot area.

Concomitant conditions have since been found to occur in other meteorological elements and appear to have their prox-

*"The rainfall of the world in connection with the eleven year period of sunspots." (Pamphlet). London and Calcutta. Thacker & Company.

imate cause in certain secular changes in the position and relation between the areas of barometric pressure over sea and land in the Eurasiatic continent and adjacent seas, entitled by Mr. Blanford, "barometric see-saw." This barometric "see-saw" between Asia and the Indo-Malayan region was found to occur in its maximum phases non-periodically so far as observations went, but it also had a smaller periodic oscillation coinciding fairly closely with the sunspot period, which when thoroughly worked out might be found to account for many of the diverse, and sometimes negative, results obtained from extra-tropical regions. Thus, to take an example. On examination of the mean annual barometric pressures at London for nearly a hundred years revealed no approach to any periodic rise and fall, but when the gradient between London and St. Petersburg was worked out by taking the difference between the two, a curve was obtained very closely imitating, and lagging constantly behind, the sunspot curve. London in this case was evidently near the axis of the see-saw beam. Were the observations of more places included, secular barometric maps could be constructed, showing not merely the amount, but the actual position and shape, of the isabnormals for months, seasons and years. The collection and elaboration of such data, the construction of such maps, and the elucidation of the results would be far beyond the powers of one man and would necessitate the employment of a large staff and the appointment of an intelligent head to initiate and control the work.

At the same time the establishment need not be permanent. A certain number of definite investigations could be decided upon, and the results from these might be regarded as a preliminary test of the utility of pursuing the investigation, and of enlarging or contracting the sphere of inquiry. The grant required, in addition to that of the existing meteorological bureau, need not be large, while on the other hand it seems hardly possible to doubt that the direct and indirect results gained by a systematic investigation of this sort would be of material and practical utility to the country.

The work to be exhaustive must necessarily comprise:

(1) The collection and analysis of all previous investigation of a similar character which bear traces of having any value, and their distribution under the head of the particular element dealt with, such as pressure, temperature, wind, etc.

(2) The arrangement of the periods in the matter of length.

(3) The choice of the particular working hypothesis intended to be employed and the working out of its supposed effects in different parts of the world.

(4) The reduction and comparison of the data representing the various elements and their comparison with the deductions from the hypothesis.

(5) The investigation of the causes of apparent exceptions and the exhibition of the final results, both in tabular and graphic form.

Many minor headings would probably be found to arise, but the foregoing represents the main outline of the scheme.

Sir George Airy * said some years ago that if all the present observatories were closed, reports stopped and the data worked up, more good would result than by continuing to accumulate millions more simply to cumber our bookshelves.

I am sure that every meteorologist who possesses a library and receives accessions to it from amateur, as well as official, workers will re-echo this sentiment. For the carrying on of the more pressing work of daily forecasting, data must necessarily continue to be amassed, and it would also be inadvisable to stop the recording and reduction of observations especially at observatories where the latest forms of self-recording instruments are employed. At the same time it appears to be highly desirable that more should be done officially to advance the science by an endeavor to discover the relations which the various elements involved bear to space, time, and physical cause. That such work would inevitably assist in rendering the ordinary daily forecasting more certain, rational, and less empirical, goes without saying, while at the same time it would probably show the limits within which it may be possible to forecast the weather of an entire season, an El Dorado of prediction which has only been attempted to a partial extent in India.

ACCESSORY PHENOMENA OF CYCLONES.

By H. Faye,
Membre de l'Institut, Président du Bureau des Longitudes, etc.

Historical.—Redfield's laws have been known in France since 1838 through a communication from the Minister of Foreign Affairs worded thus: † "The minister sends to the academy a

* The late Astronomer Royal at Greenwich.
† *Comptes rendus* 1838, t. vii, p. 898.

copy of the work of Lieut. Col. Reid upon the great hurricane which was experienced in the West Indies, and transmits the desire expressed by the author to see established in all light-houses in France a system of simultaneous meteorological observations." On this occasion, the permanent secretary, M. Arago, was naturally lead to entertain the academy with the discoveries of M. Redfield, at New York, and of Col. Reid in the service of Great Britain.* He showed that, according to these discoveries, storms should be considered as immense *trombes*, (the word cyclone did not then exist), animated at the same time by a powerful gyration around their axis and by a rapid movement of translation of eight leagues an hour. But he had to present also the memoirs of Mr. Espy and of Dr. Bache which had been received at the same time, in which these gentlemen sustained a theory diametrically opposed, that is to say, almost the same as the theories of meteorologists of to-day.

M. Arago concluded from these contradictory observations and theories that only one conclusion could be drawn, viz.: that there were two entirely different kinds of storms or tornadoes.

This obstinate contradiction, against which we still struggle, came thus early to efface the impression which these great laws had begun to make upon the mind. It turned attention from them quickly; and the laws of storms were so completely forgotten seventeen years after, at the time when the hurricane of November 14, 1854, struck our fleet in the Crimea, that it was a revelation to the whole world. What! storms travel, and cross Europe with such velocity! We must study that, said Marshal Vaillant to the director of the Paris observatory, and Leverrier, with his great intelligence and his no less great force of will, set himself at work, without suspecting that this storm had only followed the laws discovered long before in the United States.

Once on the way, another discovery was made in 1863, which was more original. The observatory of Paris originated the daily synoptic charts. In following thunder-storms upon this chart, M. Marié-Davy recognized with great surprise, that thunder-storms also traveled with great velocity with cyclones, upon a regular trajectory. Said M. Marié-Davy:† "We at first believed, with other meteorologists, that thunder-storms are local phenomena, breaking in the place where they origi-

* *Comptes rendus* 1838, t. vii, p. 707.

† Marié-Davy, "Météorologie generale," 1877, p. 373

nate. Since the first year of publication of the meteorological charts, it has seemed to us, however, that these phenomena coincide with certain movements of the atmosphere. . . . . In 1864, the coincidence of electric meteors and the passage of squalls happened so regularly, that we were authorized, after the 6th of June, to include these phenomena in the limits of our forecasts, beginning with the examination alone of the daily charts and the inflections presented by the isobars."

This indicates that the construction of storm charts began in 1865. M. Fron, entrusted with this work united the observations of all France in fifty general charts, the examination of which finally demonstrated that thunder-storms are not local phenomena, as had been believed up to that time. "They extend over a considerable part of France and sometimes traverse its whole extent. They require for their formation a certain preparation of the atmosphere, which permits the prediction of their arrival. They constantly accompany the turning movements of the air, but to produce a thunder-storm these movements have so much the less need to be strongly characteristic as the temperature is more elevated and the air more charged with vapor."

Marié-Davy* adds: "These storms come with cyclones; they appear upon the circumference of their turning disks at a certain distance from the center and propagated over long bands parallel to the route pursued by the center."

Data of Observations.—Later, the work undertaken in different countries of Europe upon thunder-storms, by Ciro Ferrari in Italy, W. Von Bezold and W. Köppen in Germany, Lancaster in Belgium, etc., confirmed and defined this first discovery. These new laws were presented as follows by M. Lancaster in his *Mémoire sur les Orage en Belgique* (1889):—

1st. Thunder-storms burst under the influence of barometric depressions.† (Our observations have completely verified this rule expressed by M. Marié-Davy in 1864).

2nd. The thunder-storm is most likely to break with us when the center of depression is found in the west, west-northwest

* Marié-Davy, ib, p. 515.

† Evidently the word depression is here taken in the sense of cyclone or of storm as may be seen in Article 10 of M. Lancaster's summary. There is a regrettable confusion to which prevailing meteorological theories lead. It is found continually in the daily bulletins of the weather, for example: The depression which yesterday reached the coast of Ireland, to-day is in England; that which has been stationary for a few days in Spain, etc. The first is evidently a cyclonic depression, a storm; the second is a purely static depression which neither turns nor progresses.

or northwest in relation to Brussels. This law furnishes the base of predictions of thunderstorms in Belgium.

3rd. Electric phenomena attain their maximum intensity over our country when cyclones have their center in Ireland or near its coasts.

4th. Thunder-storms are shown most frequently by barometric depressions comprised between 750 and 755mm (at the level of the sea).

5th. The direction of thunder-storms is generally toward the NE.

6th. Their mean velocity is from ten to twelve leagues an hour.

7th. Their production depends upon two factors, the pressure and the temperature. An elevated temperature at the time of a depression is the most favorable combination of circumstances. An elevated temperature without depression, and conversely, does not bring a thunder-storm.

8th. The hour most favorable for thunder-storms is the hour of thermometric maximum.

9th. A weak gradient is favorable to the production of thunder-storms.

10th. Thunder-storms consist of slight atmospheric depressions possessing all the characteristics of extended depressions of which they are in some sort the satellites."

I have preferred to quote M. Lancaster because it is well to show that the situation of a country, in the temperate zone, has in general no influence. If the Atlantic were on the left, instead of on the right, if it were masked by a great island like England, if it were bordered or not by a warm current like the Gulf Stream, these phenomena would occur in the same manner.

At about this time in the United States the daily tracings and study of synoptic charts lead to the same results, but with this remarkable circumstance, that to thunder-storms, to cloud-bursts and hail, were added tornadoes. They are too rare in Europe to excite any special attention. In the United States, where they are of extreme importance, especial attention has been given to these phenomena. The fine studies by Mr. Finley have led to the following law, which comprises the preceding phenomena.

"There is a definite portion of an area of low pressure within which the conditions for the development of tornadoes are most favorable, and this is called the dangerous octant, lying to the

south and east. In 287 cases the thunder-storm occurred before the tornado appeared; in 113 cases accompanying the tornado; in 57 cases after the disappearance, and in 8 cases their entire absence was noted.

Of 990 cases where the time of rain was recorded, 377 reported precipitation as preceding the tornado; 437 as following it, and 176 as accompanying it.

Of 604 cases where the time of hail was recorded, 317 reported the precipitation as preceding the tornado; 124 as following it, and 163 as accompanying it."

A last characteristic of extreme importance is, that in all latitudes thunder-storms, hail, cloud-bursts and tornadoes move in general, parallel to the trajectories of cyclones. This is clearly visible in consulting Mr. Finley's charts. It is equally true in France and Belgium. I have recently proved it for the *trombes* and thunder-storms (rare in that region) which December 1, 1887, accompanied from Sweden to Russia, in the parallel of

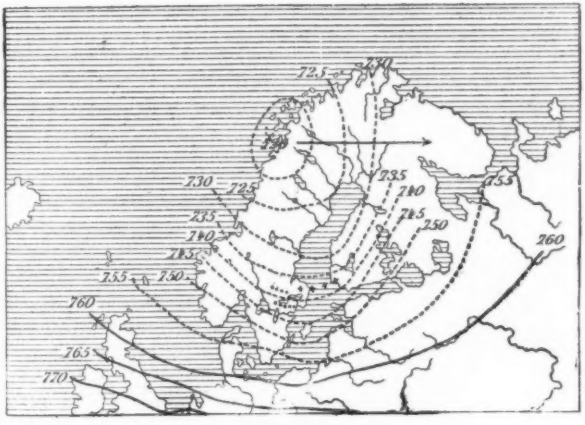

FIGURE 1.

Upsala, a cyclone whose centre passed at the same time over the Scandinavian peninsula on the parallel of Haparanda.* However, it must be said that the trajectories of cyclones are often less determined than those of tornadoes. This is occasioned by the haste with which the synoptic charts must be made for use in the daily weather predictions, and by faults in the method

* *Orage accompagnee de trombes*, by M. Wygert. Stockholm, 1888.

adopted, which consists in being guided entirely by the isobars. The trajectories thus arrived at are curious and capricious, like those found so often by M. Dechevrens at Zi-ka-wei, in the typhoons of the China seas. His successor, M. Chevalier, adopting another method for the most important points,—that of Redfield and his contemporaries,—has diminished singularly the number of these strange anomalies.

All the phenomena which accompany a storm upon its right flank, thunder-storms, cloud-bursts, hail and tornadoes, would seem very complicated if it were not understood that they are all due to whirling movements. Now nothing is more common than to see parasitic whirls established momentarily in the mouth of a principal whirl, and go so far in certain cases as to determine the segmentation.

Without considering here this extreme case, let us first establish an important difference between whirls and thunder-storms, a difference which does not at all reach its fundamental mechanism. The first are whirls that have their mouths in very elevated cyclonic currents, and which cannot descend to the ground because they have exhausted their energy before reaching it. The second originate in the currents engendered by the first at a lower height; they can descend to the ground and exercise upon it their destructive action.

Configuration of a Complete Cyclone.—Here we must return to our typical figure of a cyclone, a frustum of a cone broadly vase-shaped with the large base in the region of cirrus clouds, while its small base, where the activity of the storm is concentrated, is upon the ground.

The annular region, comprised below between the lower base and the projection of the upper base, is a region of oppressive calm or of puffs of wind (the winds prevailing in intertropical countries). Under the influence of the upper gyratory movement, the barometric pressure diminishes little by little toward the interior and modifies the natural isobars,—those which would subsist without the accidental intervention of the cyclone, and which are sometimes found there again after its passage. In the absence of prevailing winds, the barometric pressure is diminished little by little towards the base of the cyclone; the isobars are concentric to those of the storm, but with a weak gradient, and if the lower air has had time to move under this transient regime, the arrows of this feeble wind will have the centripetal movement which they take in ordinary static depres-

sions. Often there is only a calm or uncertain breezes.* It is in a determinate part of this zone that the accessory phenomena, with which we are are now to be occupied, will be produced.

The body itself, of the cyclone, above the surface presents two distinct parts, the upper region which can be seen only at the horizon, but which contains light cirrus, slightly visible and giving rise to halos or to circles around the sun or moon, and a lower region where the cirri descend into the humid strata of the atmosphere, and determine a large condensation of the vapor of water. From this a stratum of cumulus piles upon the thick nimbus, a stratum pierced by a clear orifice (the eye of the storm) and bordered below with little clouds which are detached from it, though obeying the general circulation.

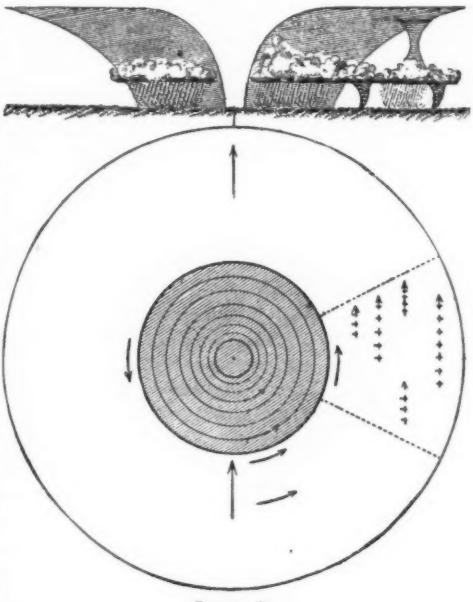

FIGURE 2.

Let us examine for a moment the succession of appearances to which the approach of this cyclonic edifice gives rise. In the first place, (five or six days in advance) the high cirri appear influenced by an upper current in the midst of which the cyclone has originated. The direction of this current is sometimes made known by the convergence of these bands of cirrus.

* If there is a prevailing wind, monsoon or trade-wind, it is slightly modified by the centripetal tendency manifested in the above mentioned annular space. Here we touch upon a case which has been in controversy for thirty years.

Upon the southern hemisphere, on the shores of the islands of Mauritius and Reunion, when a cyclone moves to the north of these islands in a direction more or less perpen-

Then come in waves the long swells, which are raised around the base of the cyclone by the violent and continual shock of the descending spirals of the whirl. A pronounced maximum of this characteristic swell takes place in the direction of the dangerous side, parallel to the trajectory, an effect similar to that which we have shown in the case of tornadoes for the projection of debris. Finally a bank of thick clouds appears at the horizon, representing the lower part of the cyclone.

The boat finds itself already engaged in the annular zone mentioned above. If the lower atmosphere is not under the influence of prevailing winds, the calm is accompanied by a suffocating heat; the barometer falls slowly, still showing the diurual period. The heavy mass of menacing clouds rises, reaches and passes the zenith; it will soon cover the entire sky. As fast as the exterior isobars close up, a light wind is felt in the direction of the winds of an ordinary depression, and, at the very borders of the hurricane, the storm breaks suddenly in squalls parallel to the interior isobars, and in the direction of the little clouds which were its forerunners. Then, and only then, the rule of eight points intervenes.

Upon the *Pilot Charts of the North Atlantic Ocean*, may be seen the "Earliest Indication" and the "Unmistakable Signs" of the approach of a storm. Only, according to my theory, the action of the first gyrations is sudden. There is no more of a gradual transition between the exterior zone of the cyclone and the circle where its action is developed than there is for a tornado between the surrounding region and that where its gyrations reach the earth. This distinction never figures on the synoptic charts. There the isobars succeed each other gradually without any indication, except perhaps, one more barb on the arrows.

(TO BE CONTINUED.)

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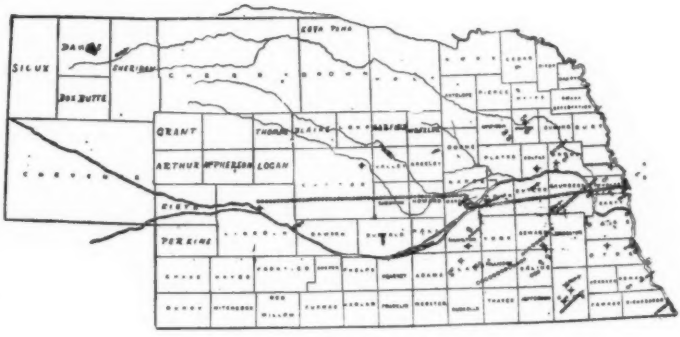
dicular to the trade-wind of the SE, there is in the said annular space, towards the south, a region where this trade-wind is reinforced little by little under the influence of the depression which precedes the storm; but it would be wrong to deduce therefrom at this time the direction of the center; it would be as inexact as if outside the trade-winds, the attempt should be made to deduce this direction from a few breezes which blow in that region, not yet reached by the cyclone. It is only by contact with the cyclone itself, that this trade-wind will begin to blow suddenly as a storm, and it is then that the rule of eight points will be applicable. Without anticipating this moment, the indices in question permit one to judge nearly the position of the center, and it may be advantageous to cut the trajectory in advance of the cyclone, that is, to fly to the north-east by putting on sail. The manageable semi-circle will thus be reached where the maneuvres are easier, and where the sails can be close reefed if it is desired to pass the danger without going too much out of the first route.



TORNADOES IN NEBRASKA.

STATE TORNADO CHARTS.—NEBRASKA.

By LIEUT. JNO. P. FINLEY, Signal Service, U. S. A.

Table I.—*Tornadoes in Nebraska.*

Period of observation, 18 years, 1871-1888.

Total number of storms,—57.

Years of greatest frequency, 1885 and 1886,—6 storms each.

Average yearly frequency,—3.5 storms.

Years in past ten (10) years, no report of storms,—none.

Months of greatest frequency, June,—17 storms.

Days of greatest frequency, April 14 and June 20,—4 storms each.

Hour of greatest frequency, 4 to 5 P. M.

Months without storms, January, February, March, November and December.

Prevailing direction of storm movement, NE.

Region of maximum storm frequency, southeastern portion.

TABLE II.—*A Chronological Table showing the location, date and time of occurrence and general character of formation and movement of Tornadoes in the State of Nebraska, for a period of 18 years, from 1871 to 1888.*

County.	Month and Day.	Year.	Time.	Direction	Form of Cloud.	Width of Path in Feet.
Dodge	June 12.	1871	5 p. m.	SSW. ?	Funnel.	1,320.
Seward	April 27.	1872	.....	NE.	"	.....
Seward	May 27.	1872	.....	NE.	"	.....
Colfax	April 7.	1875	.....	NE.	"	.....
Otoe	June 4.	1875	.....	NE.	"	.....
Lincoln	June 26.	1875	Afternoon.	NE.	"	4,000.
Gage	July 28.	1875	"	NE.	"	.....
Dodge	May 1.	1876	3 p. m.	NNE.	"	50.
Washington	May 15.	1876	Afternoon	NE.	"	.....
Gage	August 20.	1876	"	NE.	"	.....
Cass	June 20.	1877	"	NE.	"	.....
Douglas	August 25.	1877	3:30 a. m.	NE	"	.....
Saline	May —.	1878	Night.	NE.	.....	300.
Merrick, Polk, Butler, Saunders and Douglas	June 1.	1878	4 p. m.	E 10° N.	Funnel.	1,200.
Clay	"	1878	Evening.	NE.	"	1,320.
Merrick	June 20.	1878	4:30 p. m.	E.	"	330 to 660.
Hamilton	"	1878	.....	NE	"	.....
Merrick	June 1.	1879	4 p. m.	ENE.	"	400.
Gage	June 20.	1879	Afternoon.	NE.	"	.....
Douglas	May 23.	1880	6:15 p. m.	SE.	"	600 to 800.
Saunders	July 7.	1880	4:30 p. m	NE.	"	.....
Madison	September 28.	1881	12 m.	NE.	.....	660.
Stanton	September 29.	1881	Afternoon.	NE.	Funnel.	.....
Stanton	"	1881	9 p. m.	NE.	"	600 to 1,000.
Otoe	"	1881	5 p. m.	NE.	"	.....
Nemaha	April 25	1882	4 p. m.	N 40° E.	"	50 to 66.
Polk	June 24.	1882	6 a m.	E.	.....	.....
Clay	July 11.	1882	7 a m.	SE.	Funnel.	.....
Stanton	September 27.	1882	Night.	NE.	.....	.....
Clay	October 11.	1882	8 p. m.	SE.	Funnel.	.....
Saline	May 1.	1883	Afternoon.	SE.	"	.....
Saunders	May 17.	1883	4:15 p. m.	NE.	"	150.
Douglas	"	1883	6 p. m	NE.	"	.....
Douglas	June 23.	1883	Morning.	SE.	"	.....
Saline	July 13.	1883	1:45 p. m.	SE.	Cone.	900 to 2,640.
Dodge	April 26.	1884	5 p. m.	NE.	Funnel.	66 to 132.
Clay	May 5.	1884	5:10 p. m.	.....	"	.....

TABLE II.—*Concluded.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Clay, Fillmore and Saline	July 11.	1884	4 p. m.	ENE.	Funnel.	.....
Hamilton	July 20.	1884	7 p. m.	SE.	.....	2,640 to 3,960.
Lincoln	May 15.	1885	2:20 p. m.	N 30° E.	Hour glass.	.....
Douglas	June 5.	1885	7 p. m.	NE.	Balloon.	900.
Custer	June 12.	1885	Afternoon.	NE.	.....	.....
Cedar	June 14.	1885	10:30 p. m.	E.	Funnel.	.....
Otoe	June 27.	1885	1:40 p. m.	NE.	Serpent.	.....
Valley	September 11.	1885	10:15 p. m.	N 20° W. ?	Funnel.	660.
Richardson	April 14.	1886	Afternoon.	N 20° E.	Inverted Cone.	300.
Gage	"	1886	4 p. m.	NE.	Funnel.	660.
Otoe	"	1886	"	NE.	"	1,320.
Hamilton	"	1886	6:15 p. m.	NE.	"	2,640 to 5,280.
Polk	May 22.	1886	Afternoon.	NE.	"	1,320 to 5,280.
Nemaha	June 16.	1886	5 p. m.	E.	"	180.
Sarpy	May 13.	1887	5:25 p. m.	NE.	"	.....
Gage	"	1887	4:10 p. m.	NE.	"	200.
Saunders	July 14.	1887	Evening.	NE.	"	200 to 300.
Sheridan	July 25.	1887	"	NE.	"	5,280.
Butler	July 29.	1887	6 p. m.	NE.	"	1,320.
Gage	August 10.	1888	7 p. m.	NE.	"	2,640.

TABLE III.— *Relative frequency of Tornadoes by months and days, for Nebraska.*

The index figures to the right and above the dates show how many times tornadoes occurred on that day of the month.

Month.	Day of Month.	No. of Days.	Total No. of Tornadoes per month.
April	7, $(14)^4$, 25, 26 and 27	5	8
May	$(1)^2$, 5, $(13)^2$, $(15)^2$, $(17)^2$, 22, 23, 27 and (—)	9	13
June	$(1)^3$, 4, 5, $(12)^2$, 14, 16, $(20)^4$, 23, 24, 26 and 27	11	17
July	7, $(11)^2$, 13, 14, 20, 25, 28 and 29	8	9
August	10, 20 and 25	3	3
September	11, 27, 28 and $(29)^3$	4	6
October	11	1	1
Total		41	57

NOTE.—The blank (—) signifies date missing.

TEMPERATURES IN AND NEAR FORESTS.

By M. W. Harrington.

1. The problem of relative air temperatures of forests admits of a much less satisfactory solution than does that of soil-temperatures discussed in an earlier paper.* The soil is fixed and any change of its temperature is due to a flow of heat, while the air moves at the slightest impulse and is constantly mixing, thus equalizing temperatures over large areas. The motion of the air will be slow, whether it is due to a wind outside and over the forest or to a special local circulation which will be set up as soon as there is a sensible difference of temperature in the woods and out. It will be none the less effective on the average. The air also experiences more immediately the periodic and non-periodic changes in the income and outgo of heat, and is warmed and cooled more rapidly than is the soil. The result will be that the differences between the air-temperatures of woods and open fields will be less than those of the soils, and they will be more fluctuating and capricious. They will often change sign and will make less satisfactory averages.

Also, the influence of the forest on the air will not be so sharply defined at the margin of the latter as it is for the soil. It will extend outward with the moving air until it is lost, and this may be at a considerable distance. This makes the problem of forest air-temperatures separate into two distinct parts; first, the comparison of the temperature in the forest and outside, at no great distance; and second, the comparison of forest air-temperatures with those of territories otherwise like them but placed so far away that the forest does not influence them. The latter is the general problem of the differences in temperature between wooded territories and those which are treeless, and the method of its investigation must be different from that of the first or narrower problem. The first is a question of direct comparison by instruments, not far apart, and similarly exposed.

2. *The Stations near Forests.*—There are some features of the distribution of temperatures of the air outside of, but close to, a forest which require special notice because they tend to neutralize the action already mentioned and, hence, to increase the difference between the temperatures of forest and open land. The exchange of air between the forest and its neighborhood is

*See pages 263-273 of this volume.

so slow that the forest air may be considered as stagnant, and this is also true of the lee of the forest. Hence it happens that when the wind takes such a direction that the outside station is in the lee, its temperature takes on the characteristic features of those of stagnant air. The temperature will rise unusually high under insolation and will fall unusually low during clear nights. Frosts may occur at such a place when they would not occur in the forest, or outside of the forest and not in its lee. It is remarkable how slight a screen from the wind may deaden it so much as to permit a frost over the protected area. A light net, used to protect from insects, sometimes gives occasion for such frosts.

Another source of variation at stations near a forest is found in the heat-rays which are reflected horizontally by the leaves. This is very sensible in forest glades. I have been in them in the tropics when, on quiet days, the heat was nearly insupportable, while on the neighboring savanna it was not uncomfortable. In the glade the sun's rays are reflected back and forth—like a reverberatory furnace,—and the effect is much heightened. Around the forest there would be no reverberation, but it is easy to see that, as an average effect, there might be produced a ring of higher temperatures at no great distance from the margin—or more properly a ring of greater diurnal amplitudes. Such a ring was observed by P. la Cour* in Jutland, Denmark, and on the island of Zealand. The mean temperature for the Jutland series was 0.8° higher at 200 feet from the forest and 0.6° at 400 feet, than at the margin of the forest, while the diurnal amplitudes were 2.2° and 1.4° greater, respectively.

We will take up the narrower problem of the differences in temperature in woods and just outside, at a height of from four to six feet above the soil.

3. *The Observations Used.*—These are from several sources and are well scattered over central Europe.

The Swedish observations have been discussed by Dr. H. E. Hamberg† who has had charge of them. I have used the observations at the three stations: Dalboda, lat. 60° 7′; long. 17° 32′ E, altitude about 164 feet, distance between stations 966 feet; Alderstugan, lat. 59° 41′, long. 16° 17′ E, altitude about 197 feet, distance between stations about 197 feet; and Sparhult, lat. 58°

* *Oest. Met. Zeitschrift*, VII. 254–6.

† De l'influence des forêts sur le climat de la Suède. Stockholm, 1885.

35′, long. 13° 39′ E, altitude about 495 feet, distance between stations 544 feet. The period of observations was five years each for the first two and six for the last, or sixteen in all. Dr. Hamberg makes a distinction between *clairière* (glade) and *plaine*. The station in *plaine* is always at a distance from the forest station. The *clairière* or glade station is that which corresponds to the outside forest station in other services. It does not appear that it is in a glade, in the narrow English sense, but sufficiently approaches that character, generally, to make his results not so strictly comparable as could be desired with those of other services. The thermometers were placed at a height of six Swedish feet, five feet eleven inches English.

The German observations were described in the previous paper, (see p. 265, September number). In this case I have used all the observations up to, and including, 1888, as I did not observe the slight lacks of consistency in the earliest observations until the computation and reduction had been completed. The German observations sum up two months more than two hundred years. This series far surpasses all the others in the number of years of observation and, as the service is divided among seventeen stations stretching over a large territory, and is carried on under a uniform plan, the results derived from it deserve especial confidence. I have generally drawn my conclusions from it and used the other series simply for confirmation. Observations are here taken at the uniform height of 1.5m or 4 feet 11 inches.

Dr. Ebermayer's well-known publication* was founded on a year's observations at seven Bavarian and one Bohemian stations only three of which gave both maxima and minima observations through the year.† These were: Seeshaupt, lat. 47° 49′, long. 11° 3′ E, altitude 1950 feet, forest consisting of 36-year spruces; Rohrbrunn, lat. 59° 54′, long. 9° 8′ E, altitude 1564 feet, forest of 200-year oaks; Johanneskreuz, lat. 49° 20′, long. 7° 34′ E, altitude 1564 feet, forest of 60-year beeches. The observations were taken at the height of 5 Paris feet, or 5 feet 4 inches, English. The total number of years used is three.

There are three series of French observations which I have used. That of the MM. Becquerel is a series carried on with great care under the auspices of the French Academy of Sciences.‡

* "Einwirkungen des Waldes auf Luft und Boden," Berlin, 1873, Octavo, 253 pages and Atlas.

† "Einwirkungen," pp. 144-147.

‡ Published in the "Mémoires," Vol. xxxvi; the tables of results are on pp. 718-729.

The observations were made at three pairs of stations near Montargis, which is south of Paris in latitude, 48° 0′, and altitude 380 feet. The station of Chatillon-sur-Loing was in the town in a large garden surrounded by a wall. The forest station was in a grove of old trees. The second, La Jacqueminière, was in the country, in a region of mixed cultivated land and trees, as was the third, but the forest station of the latter was in a coppice containing no old trees. Only the second station would give results strictly comparable with those taken elsewhere. The height above the ground was 4 feet 4 inches. Using for a general mean, all three stations, the published observations are for three years at each, giving a total of nine years.

The second French series, in point of time, is that of M. Mathieu, of whichI have access to a brief abstract only.* They continued eleven years, (1867–1877), at three stations near Nancy, (lat. 48° 41′, long. 1° 31′ W). Cinc-Trachnées is at an elevation of 1247 feet; the forest station is in a forest of red and white beeches, the open station is in an opening of quite a number of acres. Belle-Fontaine has an elevation of 787 feet and is among 60-year beeches. Amance is 1247 feet above the sea; there was no open station for temperatures connected with this. The thermometers were four feet eleven inches above the surface. The total years' comparative observation are twenty-two.

The remaining French series is that of M. Fautrat.† The stations were in the department of Oise, north of Paris. The station at Halatte was among deciduous trees and was at an elevation of 354 feet; that of Ermenonville was among evergreens and was 302 feet above the sea. The soil of the second was a coarse sand. The observations were taken at the first from 1875 to 1877 (forty-four months), at second from 1875 to 1877 (twenty-nine months), or a total of six years. The thermometers were placed four feet seven inches above the soil.

4. *Effects on Temperature Extremes.*—The combined observations give the results of Table I. The degrees are Fahrenheit's, and the signs given are those of $W - O$, where W is temperature at forest station and O that at the station in open fields.

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* *Oest. Met. Zeitschrift*, xv, 69-70.

† *Comptes rendus*, lxxx, 1455; lxxxii 753; lxxxv, 1116.

TABLE I. DIFFERENCE OF TEMPERATURE EXTREMES.

	Observations used.	Mean of Daily Maxima, etc.					Mean of annual max. etc.	Years of observation.
		Winter	Spring.	Summer.	Autumn.	Year.		
Maxima.	Swedish	−0.96°	−4.14°	−4.56°	−2.82°	−3.12°		16
	German	−1.29	−2.22	−5.11	−2.81	−2.86	−6.25	200
	Ebermayer's	−1.00	−2.33	−5.64	−2.21	−2.80	−7.28	3
	Becquerel's	+0.47	+0.14	−2.44	−0.86	−0.67		9
	Fautrat's	−0.95	−1.57	−3.63	−2.08	−2.05		6
Minima.	Swedish	+1.50	+1.38	+1.44	+1.98	+1.55		
	German	+1.20	+1.14	+1.80	+1.36	+1.33	+4.28	
	Ebermayer's	+1.69	+0.72	+2.74	+3.44	+2.15	+9.38	
	Becquerel's	−0.23	+0.10	−0.29	−0.88	−0.32		
	Fautrat's	−0.55	−0.47	−0.22	−0.33	−0.40		
Ranges.	Swedish	−2.46	−5.52	−6.00	−4.80	−4.67		
	German	−2.31	−3.36	−6.91	−4.17	−4.19	−10.73	
	Ebermayer's	−2.69	−3.05	−8.38	−5.65	−4.95	−16.66	
	Becquerel's	−0.70	+0.04	−2.15	+0.02	−0.35		
	Mathieu's	−2.46	−4.08	−8.04	−5.16	−4.94		22
	Fautrat's	−0.40	−1.10	−3.41	−1.75	−1.65		

A simple inspection of the table shows that the forest cuts off the mean daily maxima of temperature by an amount which is very appreciable, being on the average, through the year, two or three degrees. This effect is most marked in summer and least in winter. In the latter season it is only about one-fifth what it is in the former. The spring and autumn are intermediate in character between summer and winter. The summer reduction of the mean daily maxima is less marked than the reduction of the mean annual maxima though the difference is small, averaging only one degree or slightly more.

The action of the forest on the minima of temperature is also a moderating one. $W - O$ is here positive; that is, the temperature does not on the average fall so low in forests as outside. The quantity of the effect is less than that on the maxima and there is less difference between summer and winter. In fact, in the Swedish and Dr. Ebermayer's series this effect is most marked in autumn and least in spring. For the year the elevation of the minima by the forest is about a degree and a half, and it is not very unequal in the different seasons.

The difference in range of temperature can be got by subtracting the difference of maxima from the difference of minima. It appears that $W - O$ is now negative; that is, the range in the forest is decreased, as is to be expected since the forest lowers the maxima and raises the minima. These figures may be looked on as the measure of the moderating effect of forests on

air temperature and, as such, they are instructive. It appears that in western Europe the forests temper the climate by four or five degrees on the average, and that this in summer becomes six or eight degrees, while in winter it is two or three. Between the extreme heat of summer and the extreme cold of winter the moderating effect is from ten to twelve degrees. As the rigor of a climate depends more on the range of temperature than on anything else, this action of the forest is especially noteworthy. A reduction of the mean daily ranges of from five to ten degrees is about enough to change a climate from rigorous to moderate or from moderate to mild.

5. *Permanence of the Protective Qualities.*—An interesting question is whether or not the protective effects of the forest increase with the exaggeration of the extremes. The column next to the last in Table I suggests that they do, for it shows that the average protection against the mean annual extreme is greater than against the summer maxima and winter minima. A detailed examination of the individual annual maxima of the German observations, nearly two hundred in all, shows a marked increase numerically of $W—O$ with the increase of O. Taking the centigrade values of O in groups of four degrees, beginning with 24° (that is from 24° to 28°, 28° to 32°, and so on) and averaging the $W—O$ for each group, we get the figures — 3.82°, — 5.42°, — 6.39°, — 9.20°, the latter being a mean for eleven values of O extending to 40.8°. The increase of $W—O$ is unmistakable, and there is some evidence of an acceleration in the rate.

For the annual minima the grouping brings out a different result. Taking them in groups of four degrees centigrade, as before, and beginning with — 8° for the highest, we get, in order, + 1.44°, + 2.90°, + 3.55°, + 6.03°, + 4.93°, + 3.64°, + 2.74°, the last being a mean of four, for which the lowest minimum is — 37.3°. The increase here continues with lower minima until a temperature of — 22° or — 23° C. (or — 7° to — 10° F), when a maximum value of $W—O$ is reached; after this $W—O$ decreases and approaches zero,—at which point $W—O$, or the influence of the forest on the minimum air-temperatures, would become nil. This attracted the attention of the MM. Becquerel, who found that in long-continued and extreme cold weather the woods became, not only as cold as, but actually colder than the open fields.* For instance, during a long con-

*Becquerel, *l. c.*, pp. 702-8.

tinued period of cold in January, 1868, (from the first to the twelfth) the grove station at Chatillon gave an average of 15.04° which was 2.86° lower than in the open fields. From the nineteenth to the twenty-seventh of the same month the mean was 23.76°, or 1.82° lower than in the open; from the fourteenth to the twenty-second of January, 1867, the mean was 25.72° in the grove and 0.14° higher in the open fields.

These results probably indicate the lack of staying power in the protection afforded by woods. With long continued unchanging weather the peculiarities of forest climate must tend to disappear. The insolation is periodic and the coolness of the forest in the daytime can be regained at night, though probably a continuous hot season would partially cut off this protection. The data are not in a form to enable this to be shown by them. The minimum temperatures on the other hand are due to celestial radiation and this is continuous in clear weather. With deciduous trees this would go on in the forest much as in the open, and when the cold is long continued the relative stagnancy of the forest air permits the latter to become as cold as the outside air, or even colder. The minimum belonging to the highest effect is probably the minimum for ordinary variable winter weather.

This peculiar behavior with reference to the minima of air-temperatures would not occur for the temperatures of the soil either at the surface or at any depth. The soil has another source of heat in winter, that from the soil below it, and it is especially protected from celestial radiation by the forest-litter and the covering of snow. In these cases we should find a progressive increase of the protection against minima similar to that against maxima. An arrangement in groups of the annual maxima and minima of the surface show this very plainly. In this case the maxima and minima are the means of two observations on the warmest and coldest days, respectively, as the German service does not use maximum and minimum soil thermometers. The annual maxima arranged in groups for each four degrees centigrade, beginning with 16° gives — 3.04°, — 6.25°, — 11.41°, — 15.01°, — 13.57°, respectively. The last is a mean of only five ranging from 32° to 34°. The minima give, for 0° C., — 1.13°; for — 1°, + 0.09°; for — 2° to — 5° inclusive, + 1.98°; for — 6° to — 9°, + 4.18°; for — 10° to — 16° (nine in number) + 7.38°. Here the increase of protection with exaggeration of minimum is as regular as for increase

of maximum. There were no minima given above + 1° C. At 0° C. the minimum temperatures of the surface average lower in the woods than out, and the protection becomes on the average positive only with the temperature — 1° C., or about two degrees F. of frost. Below this point the protection increases.

[TO BE CONTINUED].

RAINFALL IN MICHIGAN—OCTOBER.

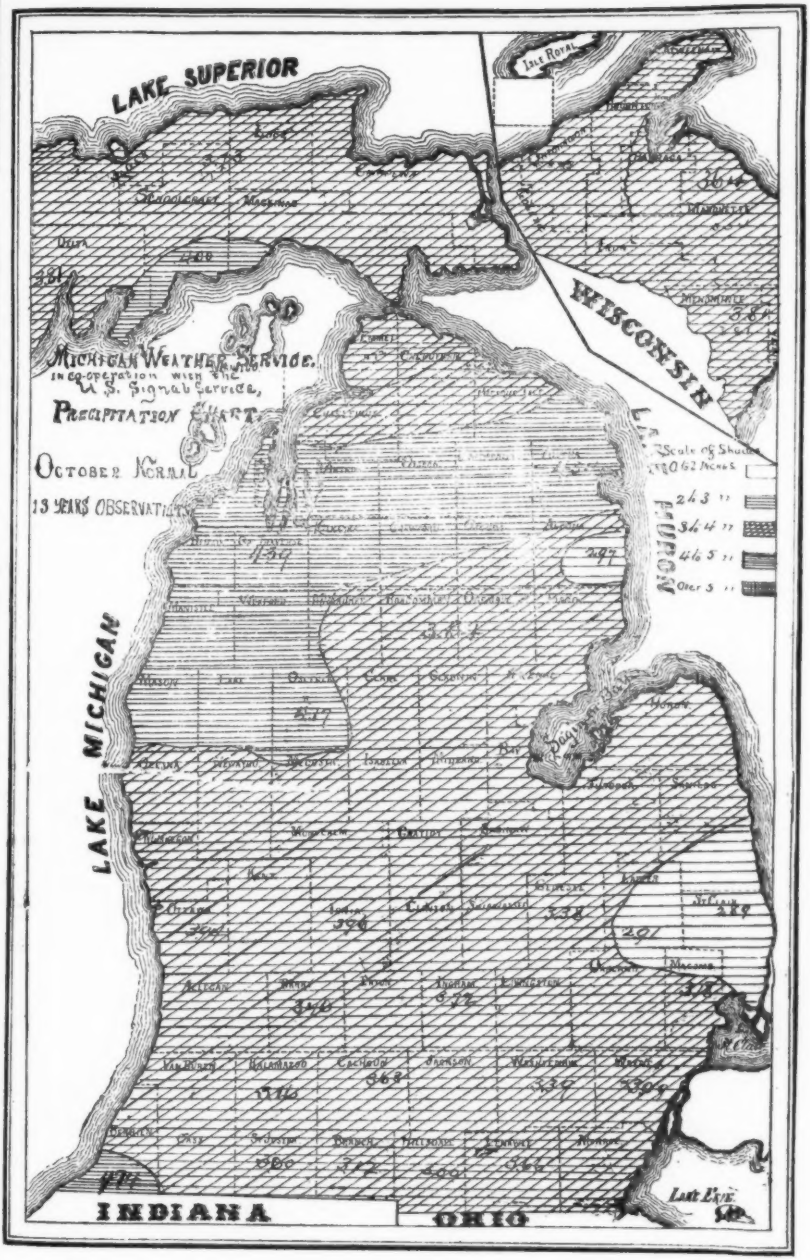
By N. B. Conger,
Director State Weather Service.

The average rainfall for the state for the month of October is 3.13 inches, a trifle below the average for September, yet the distribution is decidedly different. The amount deposited on the upper peninsula has been decreased by about one-half inch; that in the northern section increased nearly as much, and in the south half of the state the amount remains about the same with a slight decrease in the area of the light rainfall in the extreme southeast portion of the central section.

The heavy rainfall which has appeared in the different months in the extreme southwest portion of the state again appears in the southern portion of Berrien county, where the average is 4.76 inches for this month.

The rainfall for October is subject to great fluctuations, and the range of rainfall is probably greater in this month than in any of the preceding months unless it be June. The range is from over six inches to less than one-half inch. The rainfall for the month in 1889 was the least on the records in the past fifteen years, the average for the state being 2.18 inches below the normal for that period. Amounts of from seven to eight inches have been reported from nearly every section in the state during the period above named, but only in two years, while an amount of less than one inch has been reported only at one station,—with the exception of the year 1889, when a majority of the stations in the state had rainfalls of one inch or less.

An examination of the chart which accompanies this will show the distribution of the rainfall. The distribution shown in the northern section is peculiar. While this chart is as perfect as the records would allow, yet the records which have been published since the chart was made will undoubtably change its face to some extent. A larger number of stations have been


LAKE SUPERIOR
Isle Royal
WISCONSIN
LAKE HURON
LAKE MICHIGAN
MICHIGAN WEATHER SERVICE.
IN CO-OPERATION WITH THE U.S. SIGNAL SERVICE,
PRECIPITATION CHART.
OCTOBER NORMAL
13 YEARS OBSERVATIONS
Scale of Shades
0 to 2.42 Inches
2.43 "
3.44 "
4.65 "
Over 5 "
Detroit
Port Huron
Saginaw
Bay City
Alpena
Mackinac
Grand Rapids
Muskegon
Kalamazoo
Jackson
Adrian
Monroe
Ann Arbor
Ypsilanti
Lansing
St. Clair
Lake Erie
INDIANA
OHIO

added to the records than was available when it was constructed. The change will in any case not be great.

The records would go to indicate that a lack of sufficient rainfall during this month is not of frequent occurrence, and in fact has occurred but once in the past fifteen years, when the drought was of any duration or had any serious effects on the cereals of the state, which germinate during the fall months.

METEOROLOGICAL CONGRESS AT LIMOGES, FRANCE.

By A. L. Rotch.

The French association for the advancement of science held its nineteenth session at Limoges, under the presidency of Professor Cornu, August 7 to 14, 1890. The section embracing meteorology and physics of the globe was presided over by M. L. Teisserenc de Bort, chief of the department of general meteorology at the Paris meteorological office. The following officers for the meeting were chosen: Honorary presidents, Professor D. Ragona, director of the Modena Observatory (Italy), and A. Lawrence Rotch (United States); Vice-president, Dr. Fines, director of the Perpignan Observatory. The attendance of meteorologists was not large and several interesting communications were presented by title only.

Among the important papers read was one by M. Moureaux, chief of the magnetic service at the Park Saint Maur, Paris, on the magnetic anomalies in France. After having described the apparatus and the methods of observation used and indicated the precautions taken to secure the best results, the author stated his preliminary conclusions. The isogones, or lines of equal magnetic intensity, are nearly regular in northern France, but in the environs of Paris they run first from north to south and even south-southeast, and then turn northwest to resume finally their southern direction. The chart of the isanormals of the declination shows two zones of anomaly; the first, corresponding to an excess of declination, extends from Dieppe to Gien, the present limit of the observations. In the second zone, situated to the west of the first, the declination is, on the contrary, lacking. In both zones the intensity of the magnetic anomaly increases towards the south. The observed deviation from theoretical values is + 30° at Gien to — 18° at Orleans. It is as if the north pole of the magnetic needle was drawn alter-

nately towards the line which separates the positive from the negative zone; in fact along this line an increase of inclination and a decrease in the horizontal component is noted. The geological structure of the basin of Paris gives no clue to this singular anomaly which affects the declination at Paris itself. The regularity of the deformation of the isogones here in no way resembles the discordant results obtained in regions which have local influence on the compass. This unexpected phenomenon, demonstrated by these preliminary observations, seems in fact to have a more general cause, at present difficult to determine and whose investigation is dependent on the extension towards the south of the net-work of stations.

Count de Touchimbert presented a research on the truth of the weather proverb regarding a sequence of wet weather if it rains at Saint Medard, which corresponds to Saint Swithin in England. According to the investigation the truth of the proverb was partly confirmed by the data in France, though a negative result had been found by M. Lancaster for Belgium.

Rev. Fr. Dechevrens sent a memoir on the trigonometric formula of Bessel transformed into an arithmetrical operation of addition and multiplication by the help of tables. M. Teisserenc de Bort remarked that the Bessel formula for the variation of a phenomenon should not be applied without discretion, as it might lead to conclusions which had no physical existence.

Professor Ragona spoke on the annual variation of magnetic declination at Modena, which had been discussed by Bessel's formula. It was seen that the chief maximum occurred at the time of the greatest heat while the chief minimum was during the period of greatest cold, and that these phases were also dependent on the direction of the wind. M. Teisserenc de Bort remarked that these maxima and minima might correspond either with the maximum and minimum temperature of the air or soil.

Dr. Fines discussed twenty years observations of wind velocity and direction at Perpignan, tabulated with regard to the other elements. A satisfactory agreement between the Robinson cup-wheel and the Bourdon aspiration anemometers at high velocities was noted. The same gentleman also presented a discussion of four years' observations of atmospheric electricity at Perpignan. By a comparison of the registers of different stations in France it is seen that the diurnal period is not the same. At Perpignan this element had been studied in connection with other meteorological factors. Thus, under a perfectly

clear sky the potential may become negative, though it is generally positive and above the normal. Wind and dew cause perturbations which are larger during hoar-frost. Fog gives generally high positive values while rain ordinarily makes them negative, though they are sometimes positive. The rare cases of snow show positive potentials.

The Abbe Maze gave some historical details concerning the first rainfall observations in Paris about 1674, and showed how the values for the years 1677 and 1698, necessary to complete the series, might be obtained. The same speaker also discussed a formula giving periodic years of drought, $42\,n. + 1, 5, 9$, etc., in which n is the year divided by 42 whose remainder is 1, 5, 9, etc.

Professor Cornu discussed the theory of his photo-polarimeter presented to the Congress of La Rochelle in 1882 and advocated its use as a meteorological instrument for the study of the high and low strata of the atmosphere. The readings of this instrument show a diurnal period greatest at sunrise and sunset, and least at noon. The normal per cent. of polarization is about 75, but this may increase to 85 at sunset. These values should be considerably greater at high altitudes. By modifying the Wollaston prism and giving the opening the form of a grating the instrument may be used at night when there is a moon.

Mr. Rotch spoke of M. Vallot's observatory on Mont Blanc at an altitude of 14,440 feet, which he had recently visited, and stated some results of the observations on the summit of Mont Blanc (15,730 feet) and at Chamonix. The observatory at the Rocher des Bosses is completely equipped with registering instruments through the enterprise and liberality of M. Vallot, and a similar station is maintained by him at Chamonix. Other intermediate stations are projected. The observations of the barometer on the summit of Mont Blanc showed a single maximum and minimum about 3 P. M. and 8 A. M. respectively, while the diurnal period of the relative humidity presented a somewhat similar curve during the few days in summer when the observations were maintained. During the twenty-four hours of the speaker's sojourn at the Rocher des Bosses the trend of the barometric curve was downward, while at Chamonix during the same period the curve rose. The meteorological and physiological observations are to be published by M. Vallot, and the speaker thought that a discussion of the former would greatly aid the determination of the rate of decrease of temperature in

in cyclones and other problems relating to mountain meteorology.

Mr. Rotch also presented the results of the hourly observations of the amount of cloud at the Blue Hill Observatory in 1889. The night data are obtained from the Pickering pole-star recorder, of which a description was given in the report of the the International Meteorological Congress in Paris (see *Journal* February, 1890) and the means thus obtained do not differ more than one-tenth from those deduced from eye observations. For the year the chief maximum occurred at 1 P. M., and the chief minimum at 10 P. M.

M. Teisserenc de Bort spoke of the economical installation of mountain observatories, which should be multiplied on account of the interest attaching to the general study of the atmosphere, so important for weather prediction. It is not necessary to have complete meteorological observations on the mountain summits with a staff making frequent direct observations, for, owing to the progress made in self-registering instruments, it is possible to obtain accurate results without the aid of an observer, thus largely reducing the expense. These observation must be limited to the most important elements, such as the wind, the atmospheric pressure, the temperature and, perhaps, the relative humidity and the rainfall, though the latter cannot be accurately determined on a mountain on account of the influence of the topography. There are a number of automatic registers of wind directions and velocity which give fairly good results. The Richard barograph or the mercurial one of Raymond will work well for a period of fifteen days during which time the errors change but little. The same is true of the Richard thermographs which are so sensitive that two neighboring instruments give curves which coincide. Thus there is no difficulty in completing the network of mountain observatories by establishing other stations provided with self-registers whose sheets are changed each week or two, and having also direct reading instruments to serve as standards. These stations would cost, at the most, $1200 to establish and $120 a year to maintain, and would permit charts of the phenomena at high levels of the atmosphere to be drawn, thus marking a distinct advance in the study of the general movements and, consequently, in meteorology as a whole and its practical applications, such as weather predictions.

M. Garrigou-Lagrange gave some interesting facts about the

climatology of the Limousin region taken from a memoir which he had prepared from the observations collected by the departmental meteorological commission. M. Garrigou-Lagrange, it will be remembered, is the inventor of the register for the vertical component of the wind manufactured by Richard brothers. According to a statement of the Abbe Maze he (the Abbe) had proposed the motor for indicating the vertical component of the wind to the Congress of Rheims in 1880. This idea was first practically applied by the Rev. Fr. Dechevrens at Zi-Ka-Wei, China, in an instrument to which the register of M. Garrigou-Lagrange, since modified by the Richard brothers, has been adopted.

M. Y. Wada, of the Central Meteorological Observatory of Tokio (Japan) sent a memoir entitled "the recent seismic activity of Japan." After a sketch of the geological condition of the empire the author calls attention to the fact that the Japanese archipelago forms part of that great fault which surrounds the vast depression of the Pacific Ocean and which is crossed by secondary fissures extending from the ocean to the Asiatic continent. The author then discussed the hourly and monthly variations of earthquake shocks throughout Japan during fifty-three months, and at Tokio during twelve years. The seismographic observations made at Tokio show that there is a well marked maximum towards 9 P. M. and a minimum about noon, hence the author protests against the conclusions of M. Montessus at the Paris Meteorological Congress. The month in which the shocks are most common at Tokio is December, that in which they are the least frequent is September, but those having the greatest extent occur most frequently in the month of January and those of least extent in the months of August and October. In discussing the distribution of the seismic shocks according to districts the author assumes that the Japanese earthquakes are rather due to volcanic action than to simple dislocation phenomena as many Japanese seismologists believe. Finally, in quoting certain remarkable cases of earthquake shocks which have occurred in the last few years, such as those of July 15, 1888, April 1, 1889, July 28, 1889, January 7, 1890, and April 17, 1890, the author gives some approximate figures for the amplitude, the velocity and the acceleration of the seismic waves, as well as the mean velocity of propagation deduced from the seismographic observatories of Tokio and other stations of the empire.

CORRESPONDENCE.

TORNADO POWER.

To THE EDITORS:—The tremendous power generated by a tornado, a power that creates a partial vacuum tube, which being blown along near the earth's surface collapses buildings, overturns trees, and carries up lighter objects by the inrushing of air, which following nature's law endeavors to preserve an atmospheric equilibrium, cannot be satisfactorily explained by any of the known forces of nature, and efforts that have been made to account for the phenomena by attributing their development of strength to differences in temperatures of opposing bodies or currents of air and to the presence of a large amount of moisture, have signally failed. Arguments based upon the temperature, moisture, and movements of bodies of air explain the generation of the initiatory whirl of the funnel-shaped tornado cloud, but beyond that point, and in attempting to deal with the subsequent accession of power, all is vague conjecture, nor will this point be cleared up until by accident or design reliable observations of atmospheric pressure and electricity shall be obtained within the vortex of the tornado. The great difficulty, if not the impossibility, of securing such observations is apparent when the velocity of movement and small diameter of a tornado cloud at the earth's surface is considered. Impelled by a powerful upper current, its extreme end now skimming, now clearing the earth's surface, the tornado tube moves at a speed exceeding the fastest express train, and it is hardly possible in the instant of time required for the funnel to pass over a given point that a protected recording barometer located in the center of the storm's path would be sufficiently sensitive or active to register the pressure, or the eye able to follow the movement of the mercury in the tube of an ordinary barometer; the quicker action of a properly designed and constructed electrometer would doubtless result in a more accurate and satisfactory record of the electrical conditions. Assuming that the tornado is generated in the upper atmosphere by the meeting of bodies or currents of cold, dry air from the west, and warm, moist air from the east quadrants of general storms, that the condensation of moisture in the warm air rarifies and makes lighter the air at a given point, and that the inflowing air assumes a rotary motion about the place of least pressure, it may readily be seen

that an increase of strength would cause the whirl to bore its way downward, diminishing in diameter as it pierced the denser strata of air near the earth's surface, and causing air drawn towards it to ascend spirally outside of the tube, which would represent a partial vacuum. Accounting for the tremendous suction shown by tornado tubes, whereby closed houses are burst, trees prostrated, etc., the barometric gradient from the center to the outside of the tube, a distance of at most a few rods, must be very great, several inches at least, and when it is borne in mind that tornado tubes do not probably touch the ground but merely skim it, as contact with irregularities of the earth's surface would destroy its system of circulation, the partial vacuum theory as the agent of power is a plausible one. But the unsolved questions are, how is it possible for this engine of destruction to develop such enormous strength; by what agency is it possible that the funnel or tube of partial vacuum can be formed.

Before the formation of the tornado funnel clouds rush together from the northwest and southwest, their meeting being almost invariably attended by visible electrical disturbances of great energy; the tornado funnel is often reported as being aglow, apparently as the result of electrical action; persons who have been in the path of a tornado state that the air was filled with sparks, presumably electrical, during the passage of the storm centre; twigs, branches, and trees in the paths of tornadoes have been shredded by electrical action; houses and barns destroyed by tornado funnels have been set on fire, apparently by electricity; "bolts" of lightning have been observed apparently passing from cloud to earth and also from earth to cloud; marked oscillations of the needle in the surveyor's transit instrument have been noted several hours in advance of the appearance of tornadoes; and evidence seems conclusive that a tornado cloud is an electrified cloud, and that a tornado is a compressed, intensified thunderstorm. In this age of progress the mysterious element, electricity, is being closely studied, better controlled, and more and more utilized for practical purposes by practical men; its possibilities as an agent of usefulness to mankind are being recognized, and the time is not far distant when meteorologists will cease to discard, because not understood, the element of electrical influence in dealing with the problems of the weather. Beyond the fact that precipitation of moisture can be effected in an experimental way by means of positive

and negative plates, which allows of admitting that electricity may be an important agent of rainfall, practically nothing is known or admitted. Well-known meteorological writers are beginning to admit that electricity may have some connection with the development of local storms, but they can prove nothing with the appliances available, neither can they demonstrate or understand many apparently simple processes of nature, but by slight admission of possibilities they are on the right road to an explanation of what are now meteorological mysteries.

E. B. GARRIOTT.

WASHINGTON CITY, August 12, 1890.

BOOK NOTICES, ETC.

TO WHAT DEGREE IS THE PRESENT CLIMATE CONSTANT?—In a lecture before the German "Geographentag" in Berlin, Dr. Brückner, of Berlin, discusses this question in an interesting manner, and arrives at some noteworthy conclusions. He finds that: 1. Abundance or lack of rainfall occur at about the same time in all countries, and, in the course of this century, the maxima of rainfall were about the years 1815, 1850, and 1880, while the minima were about 1830 and 1860. 2. The variations are sharpened in passing from the coast into the interior of the continents. 3. The moister periods are relatively cool, the drier, warm. 4. Hand in hand with the variations of climate go certain variations in commerce. For instance the area of cultivated land varies with these variations.

ROUMANIAN METEOROLOGY.—M. Hepites, director of the Meteorological Institute, has issued the third volume of the annals of that institution. It is for 1887, and in size, form, and character of contents, resembles its predecessors. The first part is the formal report of the director of the Meteorological Institute to the Minister of Agriculture, on whom depends the work performed by the Institute. This part occupies 71 pages and is, like the rest, in parallel columns of French and Roumanian. The second part consists of two memoirs on the climate of Bucharest for 1886 (129 pages), and temperature of the air at Bucharest (47 pages). In the latter all available observations are utilized. The third part consists of the observations for

1887. This occupies the rest of the volume and fills 291 pages. The observations are for Bucharest only and are those of a station of the first order. M. Hepites seems to be yet the principal worker in the Meteorological Institute, and no one could do more alone than he does. He thoroughly deserves more aid in the undertaking in the pursuit of which he shows both competency and zeal. Roumania could not do better than to give him all the aid and support he can utilize.

THE LATEST VOLUME OF THE MEXICAN DEPARTMENT OF COMMERCE AND AGRICULTURE is the eighth, and bears the date 1887. It is an octavo volume of 500 pages and is largely devoted to questions of mining, railroads, and similar subjects. Several of the articles in it are of general interest, aside from the economic. Senor Villagómez discusses the remarkable littoral dunes about Vera Cruz (17 pages) and in the course of his article makes some interesting remarks on the "northers" which our Mexican neighbors owe to the States. Sr. Ramos's report on Lower California (168 pages) is, for the most part, given up to the interests in mining, pearls and orchilla, but it contains brief notes on the climate, rainfall, artesian wells and similar topics. Sr. Bárcena gives an account of the present state of the volcano of Colima, with some cuts.

BULLETINS OF THE U. S. GEOLOGICAL SURVEY.—Since Mr. Woodward's paper on the position of sea level, to which reference was made in the JOURNAL (Volume VI, page 38), several more bulletins have come to hand. No. 49 is on the latitudes and longitudes of certain places in Missouri, Kansas and New Mexico. No. 50 is a set of projection tables for maps. These are both by Mr. Woodward and show the same care and neatness as the paper first referred to. No. 51 relates to fossils. No. 52 is on a subject which has its meteorological bearings. It is a meteorological effect, and by changing the character of a surface, may become a subordinate meteorological cause. It is on the weathering of rocks, and is by Mr. I. C. Russell. Though treated from a strictly geological, (and chemical) point of view, it will be interesting to a wider circle of readers —meteorologists, scientific agriculturists— and its interest is by no means lessened by the several attractive illustrations it contains.

The latest bulletin which has come to hand, is No. 53, on the

geology of Nantucket, by Professor N. S. Shaler. It contains a neat colored map of the island. In the last two or three pages there is a reference to the forests, which differs from the celebrated chapter on the frogs in Ireland by its length. The facts are easily given as briefly as on the chapter on the history of Ireland, viz: "There are no forests in Nantucket." The author, however, adds that there are no signs of forests; that when trees are planted they never surpass a growth of 20 feet; and that the tradition of former forests is untrustworthy. Then he proceeds to give sufficient reasons for the deforestation of the island.

It may not be known to some of our readers that the publications of the survey can be purchased of the director at very moderate prices:

Mr. Woodward's "Sea-level" costs ten cents, and his "Projection Tables" fifteen cents.

Mr. Russell's and Professor Shaler's papers cost ten cents each.

"DEUTSCHES MET. JAHRBUCH, 1889, BARYERN."—Beob. der Met. Stationen im Konigreich Bayern, Dr. Carl Lang, director; Jahrgang XI, Heft 4, quarto, 166 pages; Jahrgang XII, Heft 1. Quarto, 38 pages; Munich. These publications contain an abstract of the observations of the Bavarian service, published on the International plan. The first also contains: Comparison of two thermometer shelters (7 pages), observations of thunderstorms in Bavaria in 1889 (11 pages); meteors and earthquakes (3 pages), velocity of thunderstorms in south Germany (11 pages), thunderstorm of Sept. 27, 1889 (2 pages and maps), soil temperatures at the observatory of Munich and their relations to the weather (24 pages).

ON DIFFRACTION COLORS WITH SPECIAL REFERENCE TO CORONAE AND IRIDESCENT CLOUDS.*—In a previous paper the writer has explained the occurrence of bright colors in certain clouds near the sun on the hypothesis that the light is diffracted by thin needles of ice or by fine drops of water. In the present paper he gives a more complete determination of the actual colors produced, based on Maxwell's observations of the color relations of the solar spectrum. The first section contains a

* By J. C. McConnel, M. A. Phil. Mag., October, 1889, page 272.

mathematical investigation of the light diffracted by clouds of filaments and of spherules respectively. The second is devoted to calculating the colors and setting them out on Maxwell's diagram, with the approximate colors of the sky and sun. In a future number the author hopes to publish additional remarks on iridescent clouds and allied phenomena, including Bishop's ring. "The outlying spectra from water-drops are about twice as bright as those from ice filaments, when the drops and the filaments occupy the same fraction of the field of view, and corresponding spectra are at the same distance from the sun." The comparative poorness of water iridescences is perhaps due to the fact that in ordinary clouds the drops are for the most part opaque. In the colors of iridescent clouds formed by needles of ice, compared with thin plates, the long wave lengths have an advantage; and the curve is on the whole displaced from the violet towards the red; the colors are, on the whole, purer. The author notes some observations made on February 25, 1889, of colors in ice-clouds, in which the tint seemed to depend mainly on the distance from the sun; in order, outwards, yellow, bright red, purple, green, greenish yellow, faint pink. A few minutes later the purple had altered to faint purple, bright blue, and the outer pink was succeeded by purple and green. "It is now certain that the blue of the sky and the reddish tinge of the setting sun are mainly due to the scattering of light by particles small compared with a wave length. The theory of this action is due to Lord Rayleigh." The colors of the sunlight traversing 5, 10, 20 and 40 atmospheres are respectively yellow, yellow inclining to orange, a fine orange and a red deeper than red lead. If we could look at the ordinary blue sky through a tube filled with air, 25 miles long, it would appear pale greenish white. A. M.

WINDS, OCEAN CURRENTS AND ICE PERIODS.*—This pamphlet, consisting of three chapters with headings indicated by the title, is written by an evidently earnest searcher after the causes of these three great existing features of physical geography. In his preface he says: "In the following pages, I have endeavored to give in a plain and simple manner what I consider to be the principal causes which produce the great prevailing winds and ocean currents, and also to explain how through their action great climatic changes have taken place during ancient eras sufficient to

* By C. A. M. Taber. pp. 86. Boston, 1889.

overrun with ice the now temperate zones. And, furthermore, I have attempted to show that the conditions are favorable for the climate of regions situated in the high latitudes of the southern and northern hemispheres to be slowly growing colder, and that considerable progress has been made since the last frigid epoch ended for the gradual return of another ice period both in the northern and southern latitudes of the globe. I have also, in the third chapter, pointed out localities in the southern portions of North America where I think that greater work has been performed through glacial action than has yet been attributed to it."

As almost each page of this pamphlet treats of a separate topic coming under the general heading of the chapter, a great variety of points are touched on; rather more, in fact, than ought to receive original treatment in such a limited space as can be found in a pamphlet of this size. The author admits that his views are opposed to those of other writers on these topics, especially as regards the causes of the great currents of the atmosphere, and he must expect his reasoning to be questioned by those students of Meteorology who are inclined to believe that the most probable explanations of many of the phenomena mentioned in the pamphlet have already been given. To the reviewer chapter three is the most interesting, as it contains many facts relative to past and present climate, that he had not met with before.

SONNBLICK METEOROLOGY.*—Of the many excellent contributions of Dr. Hann to meteorology, perhaps none have greater present interest than his studies of the meteorological observations made on and around the peaks of the Alps. Meteorologists are more and more looking to a knowledge of the conditions in the upper air to aid in solving many of the problems of the weather. Not content with isobars and synoptic charts for the earth's surface, the more advanced meteorologists are seeking to construct them for the upper air, and for this reason a knowledge of the law of the vertical decrease of temperature and allied phenomena are much desired.

The great scientific interest in these problems abroad—much of which has been stimulated by Dr. Hann—has led to the establishment of a number of meteorological stations on peaks

* *Zur Meteorologie des Sonnblickgipfels*, von J. Hann. (Separatabdruck aus der Zeitschrift des Deutschen und Oesterreichischen Alpenvereins, 1889. Band XX).

at different heights among the Alps. The highest of these is the Sonnblick, a description of which is given in this JOURNAL, Vol. III, page 385, (December, 1886). This station has been in operation since September, 1886, and the observations compared with those at successively lower levels have enabled Hann to study the atmosphere section by section as it were. The heights of the stations used for this purpose are as follows: Sonnblick, 10,170 feet; Säntis, 8,087; Obir, 6,716; Schmittenhöhe, 6,398; Kolm-Saigurn, 5,315; Zell am See, 2,493; Lenz, 2,231.

Since the discontinuance of Pike's Peak station the Sonnblick is now the highest meteorological station in the world. Hann expresses regret that so little of the observations made at Pike's Peak is accessible; but fortunately this lack has been supplied by the liberal interest of Professor E. C. Pickering, who has published the entire series of observations.

The mean temperature at the Sonnblick station during 1886 was found to be 19.6° F., and during 1887, 18.1° F. The mean winter temperature was 8.0° F.; and the mean summer temperature was 32.5° F. Hence, although so near the sunny climate of Italy, the annual temperature corresponds with that of central Spitzbergen and Greenland; and the mean summer temperature is lower than that of any station in the northern hemisphere. The highest temperature yet observed is 50° F., and the lowest — 29° F. It is thus seen that there are many stations in the world which have lower absolute temperatures than on the Sonnblick; but Hann points out that in these places the very low temperatures generally occur with calms; while at mountain stations they generally occur with the severest gales, so that the thermometer readings do not give an accurate idea of the relative effect of the temperature on an individual. The difference between the mean temperature of January and July on the Sonnblick is about 26° which is much less than at stations in the same latitude near sea level. By comparing the annual ranges found at stations at different elevations mentioned above, Hann shows that the annual range of temperature decreases with elevation above earth's surface; and by extending this regular rate of decrease upward above the Sonnblick, he finds that at a height of about 30,000 feet the temperature probably remains constant all the year around. This is approximately the height at which cirrus clouds float.

In regard to the decrease of temperature with height, he found that up to three or four thousand feet above the earth's

surface the decrease was very variable. In cold clear weather it was generally colder at night at the earth's surface than at a height of one or two thousand feet. Above this the decrease was nearly constant for all altitudes; but varied from 1° F. in 328 feet in January to 1° F. in 243 feet in June, the average for the year being 1° F. in 282 feet, or 0.35° F. for every 100 feet. In Glaisher's celebrated balloon ascents, some of which extended to a height of 30,000 feet, he found that the rate of decrease of temperature grew less with the height, and at great altitudes was only 1° in 1,000 feet. This does not appear to be confirmed by Hann's results, but perhaps it is because they do not extend to sufficient height. The rate of decrease varies with the time of day. Hann finds the average rate of decrease for the year to be 1° F. in 296 feet at 7 A. M. and 9 P. M.; and 1° F. in 235 feet at 2 P. M. This same proportional difference for the hours holds approximately true throughout the year.

In regard to the amount of cloudiness and sunshine, he finds that the climate of the Sonnblick station is almost the reverse of that near sea level. On the Sonnblick the least cloudiness occurs in winter, and the most in summer; while at Kremsmünster the most occurs in winter and least in summer. This was largely due to the fact that the lowlands and valleys were frequently enveloped in fogs and covered by low clouds during the winter which did not extend to the mountain peaks; while in summer the mountain peaks were often enveloped in clouds, especially during the afternoon, which caused the amount of sunshine to be less than at lower levels. Hann was also able in several cases to connect stormy and rainy weather on the mountains with the excessively dry and warm *fohn* in the valleys.

Hann's researches also promise to throw much light on the causes of cyclones and anti-cyclones; and so varied and important have been his results that it makes one regret that more interest has not been taken in such observations in this country. H. H. C.

THE "CHALLENGER" RESULTS.*—This volume is of interest on account of the discussion by Buchan of the meteorological observations made every two hours on board of the *Challenger* during the extensive cruise, of three years duration. In the

*"Report of the Scientific Results of the Exploring Voyage of H. M. S. *Challenger*," 1873-76. Physics and chemistry, Vol. II.

discussion Buchan has not confined himself to the observations on the *Challenger* alone; but has utilized all of the available observations over the world and drawn up monthly and annual synoptic charts of the pressure, temperature, and winds from the best and most recent observations in every country and on every ocean. In this way he has been able to discuss the observations of the *Challenger* with the fullest possible light, to contrast the phenomena observed over ocean and over continent, and thus farther enrich meteorology, with those broad generalizations for which he has become famous.

The only fault the present writer would find is in the exposure of the instruments on board the ship, which, from the diagrams given, does not remove all fear that the temperature may not have been somewhat affected by the local causes on the ship.

The report extends to 342 pages of letterpress, and is illustrated by two plates of diagrams and fifty-two newly constructed maps, showing the monthly and annual distribution of temperature and pressure of the atmosphere and winds over the globe. Of these fifty-two maps, twenty-six show the mean monthly and annual temperature on hypsobathy-metric maps, first on Gall's projection, and second on north circumpolar maps on equal surface projection; and twenty-six show, for each month and for the year, the mean pressure of the atmosphere, and the winds. From the hypsometrical data tinted on the charts the influence of height on the distribution of pressure, temperature, and other meteorological phenomena may be noted, this influence being more particularly observed in those parts of the world whence observations from numerous stations are available.

The following are some of the most important results obtained from the discussion of the *Challenger* observations:

The observations made on the surface temperature of the sea showed that "the general diurnal range of temperature near the summer solstice is a little less than a degree." "The mean daily range deduced from the whole of the observations made during the three years and a half is 0.8°." The minimum occurred about 5 A. M. and the maximum about 3 P. M.

From the observations of the air temperature it was found that "the mean daily range of temperature of the air in the anti-cyclonic regions of the four great oceans is 3.2°; in the neighborhood of the equator where the sky is more clouded it is about a degree less. In high latitudes the daily range is much

less," averaging about 1.5°. "The general result is that the daily range of temperature of the air on the open sea is from three to four times greater than that of the surface temperature of the sea over which it lies." The minimum temperature occurred about 5 A. M. and the maximum about 2 P. M. "It is interesting to note the frequency with which the mean daily temperature occurred as early as noon when the *Challenger* was in harbor, a result probably due to the diurnal period of the sea breezes in such situations in tropical and sub-tropical regions. Generally speaking, at high level stations, and in situations within the influence of well marked sea breezes, the time of the occurrence of the daily maximum temperature is about two hours earlier than in inland open situations."

Over the open sea, at a distance from land, the variation in the tension of vapor in the air shows a single minimum and maximum corresponding with that of the temperature. "Over the land the [absolute] humidity daily curve shows two well marked minima and maxima." "The hygrometric observations made near land show a daily humidity curve intermediate between these two." The relative humidity of the air follows a curve inverse to that of the temperature for all climates and all seasons "subject, however, to a slight increase in seaside climates during the hours of the prevalence of the sea breezes."

The hourly barometric oscillations observed on board the *Challenger*, when reduced and compared with those observed at adjacent land stations, show that "on small islands such as Ascension, and St. Helena, and, during the rainy season of such localities as Havana, Bombay, Hong Kong, and Zi-ka-wei, the amount and times of occurrence of the maxima and minima closely agree with what were observed on board the *Challenger* over the open sea in like latitudes."

"Among the most valuable of physical results arrived at from the observations made on board the *Challenger*—valuable from the important conclusions to which it leads—is the fact that the diurnal range of the mean surface temperature of the sea does not anywhere exceed a degree Fahrenheit, whilst the diurnal oscillations of the barometer occur over the open sea as well as over the land surface of the globe. It follows, therefore, that the atmosphere over the open sea rests on a floor or surface, subject to a diurnal range of temperature so small as to render the temperature practically constant both day and night.

"This consideration leads at once to the all-important conclu-

sion that the diurnal oscillations of the barometer are not caused by the heating and cooling of the earth's surface by solar and terrestrial radiation, and by the effects which follow these diurnal changes in the temperature of the surface, but that they are primarily caused by the direct heating by solar radiation, and cooling by nocturnal radiation to the cold regions of space of the molecules of the air and of its aqueous vapor."

The morning minimum of pressure, and morning maximum, he explains as due to a decrease and increase respectively in the tension of the vapor of the atmosphere.

"The diurnal curves of pressure are liable to large modifications according as the earth's surface in the immediate neighborhood of the barometer from which the observations are made presents a level plain, a troughed hollow between mountains or rising ground, or isolated peak."

"Over the ocean in high latitudes the diurnal curves of pressure show only one maximum and one minimum, but the times of their occurrence are directly opposite to those over land."

The cloud observations showed two diurnal maxima and minima. The chief maximum occurred about sunrise, and the other in the early part of the afternoon. The chief minimum extended from sunset to midnight, and the other occurred about noon. "But the difference between the extremes is only six per cent. of the sky."

"The daily period in the frequency of occurrence of rain over the open sea is simply inversely as the temperature."

"Over the land the maximum of thunder-storms occurs during the hours of the day when temperature is highest, but over the open sea during those hours when temperature is lowest." H. H. C.

THE INFLUENCE OF A COVERING OF SNOW ON THE GROUND, ON CLIMATE AND ON WEATHER.*—This model treatise surprises us in two very different ways; in showing how much of interest and importance can be drawn from the generally unsystematic observations now on record, and in showing how much remains to be done in this neglected field, the importance of which seems to have been much underrated. The author's conclusions number thirty-six, and as these are precisely formulated, and as the sub-

*Der Einfluss einer Schneedecke auf Boden, Klima und Wetter, von Professor A. Woeikof. Penck's Geog. Abhand. Band III, Heft 3. Wien, 1889. Large octavo, 116 pages.

ject is one of especial interest in the United States we will translate them for our readers. They are:

1. The snow, as a bad conductor of heat, protects the ground from cooling during the entire time that the temperature of the air and of the surface of the snow is below the freezing point.

2. This effect is, with equal depth of snow, the greater in proportion as the snow lies lighter. It is notably less when the snow is soaked with water or is icy.

3. At temperatures above 32° the effect of the snow is the opposite, that is cooling. This cooling effect lasts after the snow is melted, because the soil is then filled with water at 32°, and this warms up slowly.

4. On the whole, therefore, the snow lessens the fluctuations of the temperature of the ground.

5. The warming effect of a snow covering is greater than the cooling, and the more, the longer the snow continues in temperatures below freezing. With a snow covering of twenty inches depth and over six months continuance, the temperature of the soil at a depth of three feet is probably not lower in the coldest months than the annual temperature of the surface or that in the lower layers of air.

6. By the surface is here meant the surface of the snow when present, and of the soil when there is no snow.

7. The temperature on the surface of soil free from snow is higher than that of the surface of the snow.

8. This is due to the physical properties of the snow,—on its capacity for radiation, on the impossibility of warming it above 32° without melting, and on its bad conducting power which, so to speak, concentrates the cold on the surface.

9. Since the temperature of the lower layers of air depend to a great degree on the temperature of their bed, whether this is solid or liquid, this temperature must be lower, other things equal, over snow than elsewhere.

10. As the cooling of a snow surface, as compared with one free of snow is greater in clear than cloudy weather, this relation must also hold for the lower layers of air.

11. The cooling of the air over a snow layer is so great that it can be shown by ordinary meteorological observations without requiring the use of especially sensitive instruments.

12. When snow lies on the ground, we generally have a so-called reversal of the temperatures; that is, the lowest air layer is colder than that somewhat higher; this may happen in the middle of the day, especially in calm and clear weather. The reversals of temperature between valleys and neighboring heights, that is, lower temperature in the first, happens most often over a snow surface.

13. The rough surface of the snow and the cold air lying over it lessen the force of the wind.

14. This tends to preserve the snow surface by weakening the effect of warm winds.

15. The lessened wind velocity and also the colder air are favorable to the formation and continuance of anti-cyclones over a snow surface.

16. The blizzards (Buran, Kriwitz, Purga), often so terrible, are by no means always accompanied by wind strong enough to cause injury to buildings, trees, etc. Their injurious effects are due to the driving snow, and it is that that robs men and cattle of their senses.

17. On account of the evaporation of the snow, the relative humidity is greater over a layer of snow than without it.

18. The evaporation of the snow is small, because its surface is at a lower temperature than the air.

19. The influence of a snow covering on the cloudiness differs with the circumstances. The greater relative humidity is favorable to a greater cloudiness, while with the anti-cyclones, favored by the snow, there is usually little cloudiness.

20. The impossibility of warming snow over 32° has a great influence on the temperature of the air. Thawing weather in winter over an extended covering of snow is of short duration; the temperature rises but little over 32° and that only as long as the warm wind lasts. With cessation of wind and clearing sky, the temperature rapidly sinks below freezing.

21. In spring (in lower latitudes in winter also) there are days when, in calm weather and full sunshine, the temperature rises above freezing, even while the snow lasts. In these cases the air is warmer than the snow. When there is no snow, in full sunshine, the surface of course is always notably warmer than the air. The phenomenon above mentioned is always of short duration and has no great effect on the mean temperature of the air.

22. The snow thaws but little, if at all, under the direct sun's rays, as long as the air temperature is below freezing. Hence, the melting of snow in quantity only begins when a mass of warm air from a region free of snow, or from a sea free of ice, has raised the air temperature above freezing.

23. On the northern hemisphere, therefore, the melting of snow proceeds by steps from south to north, and from west to east because the seas to the east of both continents are cold.

24. Without the influence of warm air, the air temperature remains below 32°, even in May and June, in high latitudes, so long as the snow remains.

25. On the northern hemisphere in summer, up to the highest latitudes, there is enough water free of ice or land free of snow to provide in June a sufficient flow of warm air to bring about the melting of snow in quantity. Even in the highest latitudes the snow melts during the summer on the plains and the sea coast and the temperature is above 32° for a month or two.

26. That this phenomenon is not universal appears in the higher latitudes of the southern hemisphere, where, south of 62° S, the mean temperature, even in mid-summer, is below 32°. At 78° S it is even under 25°. Here the warm air has to traverse a distance of 600 miles over a water surface cooled below freezing; it is thereby so much cooled that it cannot thaw the snow of the south polar continent.

27. The low temperatures which occur in regions without snow covering, as on the plains of Turkestan and the plateaus of central Asia, can be attributed to the following causes: (*a*) In some cases snow falls

and is generally followed by intense cold due to radiation. It is very severe because there is little cloudiness and the air is diathermanous. (*b*) Especially in central Asia, the winds are strong, the air is dry, the soil dries to a great depth and becomes a bad conductor of heat. Its surface then cools rapidly, especially if it is sandy. (*c*) Low temperatures are often brought by winds from countries covered with snow, as on the plains of Turkestan from western Siberia.

28. The melting of the snow affects the rivers greatly, and on it depends the regular highwater of the rivers of European Russia and west Siberia.

29. The height of water in small rivers and brooks in spring depends not only upon the quantity of snow lying on the ground, but also upon its more or less rapid melting and on the circumstance whether the ground is frozen to a great depth or not. If the former the soil is impenetrable for the water and the latter quickly reaches the streams. If deep snow has fallen on unfrozen ground, on its melting very much of the water passes into the soil, as in the spring of 1888 in central Russia.

30. The air temperature on isolated mountains depends much less on that of the surface than that of the valleys and plains; hence a covering of snow is in this case of relatively little influence.

31. A snow layer on mountain ridges cools the air in spring and summer to a notable degree and so causes often an unstable equilibrium of the air layers, in a vertical direction.

32. The Bora of the east coast of the Adriatic and of the Black Sea is especially violent when there is the unstable equilibrium which is due to the contrast of temperatures between the snow-covered mountain chains and the warm sea coast.

33. The mountain streams, which are fed by glaciers and compacted snow, have often much water in dry years because at such times more snow melts than falls. Years of abundant snowfall in the region of continuous snow are not always followed by high water in the streams, because then the snow mass is increased.

34. The snow which falls in mountains has a marked effect on the weather which follows in the valleys and on the plains at the foot of the mountains,—and not only on the temperature, but also on the air pressure and the rain. This has been proven for northern India and has been shown to be very important for the prediction of the weather.

35. The influence of a snow layer on air pressure, temperature and humidity always increases with the extent of the territory covered; hence more anticyclones and a lower temperature are to be expected in the center of a territory covered with snow than at the edges.

36. The snow lying on ice and ground in high latitudes lessens to a considerable degree the cooling of the solids and of the water.

Professor Woeikof also calls attention to the desirability of farther studies of snow and points out the way in which such studies should be made. Systematic observations on snow were begun in Bavaria—a country often in advance in systematic meteorological observations,—in 1886. Since the summer of

1888 much attention has been given to the subject in Russia and the aid of the railroads has been enlisted. The presence and depth of snow is of enough importance to enlist the general meteorological services, especially in such countries as Canada and the United States where enormous regions are often covered. Daily reports ought to be made and the results might well be included in those utilized for the synoptic charts.

But there are many things which the individual observer, who is not in a large city, can do. The depth of the snow should be measured regularly even when no fresh snow falls. Its density should be determined from time to time by melting a measured quantity and comparing the quantity of water with that of the snow. In mountainous regions especially must attention be paid to the snow and to its limits. To observations of such character travellers and hunters could add much of value.

The temperatures of the soil, when covered and uncovered, should be taken; also temperatures of the air at several heights and at different hours of the day. The exceptional cases, such as that described in (21) above, should be especially investigated. Careful observations should be made on the conducting and radiating power of snow, and on the comparative evaporation of snow in different physical conditions.

The following paragraphs are from the instructions for observations of snow issued by the Meteorological Commission of the Imperial Russian Geographical Society:

It is desirable that the depth of snow be measured at two places,—one unprotected, not less than 125 feet from buildings, fences, trees, etc., the other protected from the wind, as in a garden, on a forest meadow, etc., yet so far from trees that the snow which falls from the limbs can not reach the place of observation.

The observations should be made with staffs which are divided into centimeters [in this country half-inches], and marked with colors so that they can be easily read at the distance of five paces. The zero of the scale should be at the surface of the ground. With the first observations should be given approximate distances of the staff from the nearest buildings, trees, etc. Under the heading of "character of vicinity" should be given information as to the immediate and commanding topography.

The readings of the staffs are to be made daily at 7 or 8 A. M., and from a distance of five paces.

All noteworthy facts should be recorded,—as when the snow fell, whether it was driven by the wind or not, when thaws and rain came, how they affected the snow, when a crust is formed and when this falls apart into single grains under the influence of dry air or strong wind.

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